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LATE PALEOZOIC XIPHOSURANS

BY PERCY E. RAYMOND

WITH TWO PLATES

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No. 8—*Late Paleozoic Xiphosurans*

By Percy E. Raymond

The Xiphosura from the Carbondale series (mid-Pennsylvanian) of Mazon Creek have long been known, but never critically studied. The collections recently made by Mr. Frederick Thompson contain several unusually good specimens presenting new points of interest, so the time seems opportune to restudy the material from that region, and to make comparisons with other related forms recently described.

The specimens from Mazon Creek and vicinity are in a peculiar state of preservation. Like the plants, they are found in clay-ironstone concretions in which they are comparatively little crushed. Such distortion as is present is probably due largely to the thinness of the test, which appears to have been much less strong than that of modern limulids.

The specimens seem at one time to have been hollow molds, with a space between the tergal and sternal tests. This space in some was later partially filled with pyrite; in others it contains a soft white platy substance which Professor Cornelius S. Hurlbut, Jr., identified for me as kaolin. Some specimens retain a thin coating of pyrite, others have crystals of the same mineral imbedded in the kaolin, and still others have nothing but kaolin. This substance can be removed mechanically from such specimens as have a hard matrix, and good molds of the dorsal and ventral surfaces secured.

I am indebted to Dr. Carl O. Dunbar for the loan of many specimens from the Peabody Museum at Yale University, to Dr. Ray S. Bassler for casts of types in the United States National Museum, and to Dr. Christina Lochman for a specimen. For the photographs, thanks are due to Prof. Frank M. Carpenter, who collected the Permian specimens. The drawings were made by Dr. Robert R. Wheeler. Mr. Frederick Thompson has generously presented many specimens to the Museum of Comparative Zoölogy.

TERMINOLOGY

Dorsal Surface

Authors have used various terms for the parts of the test of xiphosurans. There has been little usage of the same term with different meanings, so there is little real confusion, but it may be well to explain the terms used in this paper. I shall follow the usual custom of naming parts so far as possible, by analogy with the trilobite.

The anterior shield is a cephalothorax, since it has six pairs of

appendages. The term *prosoma*, now in general use, applies well to it. The terminal segment of the body is so generally known as the *telson* that no better name need be sought. But the median portion presents problems.

In the primitive xiphosurans of the Silurian and early Devonian, this part of the body consists of free segments. One is tempted to call it a thorax, but this can not be done, for the last segment bears the anal opening, showing that the telson is not homologous with the pygidium of a trilobite. In cases where all the segments are free it seems best to follow the general usage and employ the non-commital term *trunk* to this portion of the body.

Modern xiphosurans have a single median shield. The anterior portion bears six pairs of appendages, the posterior part none. The anterior section is called the *mesosoma*, the posterior the *metasoma*. This would be an excellent usage, were it not for the fact that it is impossible to correlate the parts with those of Carboniferous members of the group. The consolidation of the trunk segments into a single shield appears to have begun at the posterior end. Some species of Belinurus seem to have five, others seven, or even so few as four free segments in front of a fused portion next to the telson. Hence the obvious subdivisions of the trunk do not correspond exactly to the meso- and metasoma. The application of these terms to fossils is involved with theories. Moreover, a single word is needed to designate the single median shield of the later members of the group. Packard called it the *urosome*, an unfortunate term, for it is not a tail. Neither is it an abdomen in any sense of the word, although often so designated. Dix and Pringle have lately revived Sir Richard Owen's term *thoracetron*, a usage which will be followed here. They applied the same name to the trunk of Belinurus, but it seems better to restrict the term to shields which are completely consolidated. This leaves us with no satisfactory terms for the parts of the trunk of those forms in which fusion was in progress. Perhaps *promesosoma* and *prometasoma* will be satisfactory.

A distinctive feature of the dorsal surface is the presence of a pair of longitudinal furrows, limiting a relatively narrow median lobe on both shields. These suggest comparison with the dorsal furrows of trilobites and the inference that the median lobes are homologous in the two sorts of animals. This is almost certainly true of the anterior part of the thoracetron, for entopophyses for the attachment of muscles project downward beneath them, just as do the appendifers of trilobites. Whether the median lobe of the prosoma is homologous

with the trilobitan glabella is still debatable. Packard called the median lobe of the thoracetron the *cardiac lobe*; Dunbar has used the same term for its prolongation on the prosoma, and it seems logical to adopt the term for the entire median lobe.

Fully as conspicuous as the dorsal furrows on the prosoma are the longitudinal ridges behind the eyes. In Limulus they extend only a short distance in front of the eyes, but in many of the Paleozoic forms they converge forward, meeting on the median line. These are the *opthalmic ridges*; the area enclosed within them, including the cardiac lobe, was called the *cardio-opthalmic* region by Packard, the *glabella* by H. Woodward, and the *cranidium* by Willard and Jones. The first of these is preferable, since it is non-commital as to homology. For convenience it may be shortened to *cardiopthalmic*. Dunbar subdivided this region into the median cardiac lobe and the lateral *"glabellar" lobes*, but it would seem better to avoid implications as to homology by applying some such term as *intra-opthalmic* to the areas between the dorsal furrows and the opthalmic ridges.

These intra-opthalmic areas, in Limulus, have obscure transverse depressions which alternate with thickened areas in the test. The transverse furrows on the surface find expression on the inside of the shell in curved ridges which bound the margins of muscular areas. The muscles attached underneath the convex areas between the depressions are those which extend either vertically or diagonally downward to the borders or outer ends of the coxal segments of the second to sixth legs on the prosoma. Most of the scars are adjacent to the outer side of the ridge beneath each of the longitudinal furrows bounding the cardiac lobe. The transverse depressions are intermuscular, and probably correspond in origin to the glabellar furrows of a trilobite. In the latter animal, however, the furrows extend mesially from the dorsal furrows in all except specialized members of the group (e.g., Acidaspidae, Lichadidae). Hence it seems doubtful if the whole cardiopthalmic area is homologous with the true glabella of the trilobite.

Ventral Surface

The ventral membrane of Limulus is sufficiently chitinized to retain a definite shape. The marginal portion, surrounded by a thickened edge, is approximately horizontal. This portion corresponds with the *doublure* of a trilobite, and will herein be mentioned by that name. It is bounded posteriorly by ridges which curve backward abruptly near the front and meet in a mesial spine. The roughly triangular region

(*sub frontal area*) thus set off is beneath the stomach. From the thickened ridges the ventral membrane rises in broad vaults, approximately parallel in convexity to the dorsal shield. The membrane is not fully chitinized toward the summit of the vault, hence has considerable flexibility. The uppermost edges are escaloped, with thickened buttresses which unite to form fulcra (*coxal attachments*) for movable articulation of the five appendages behind the chelicerae.

The median portion of the ventral surface is occupied by the appendages. As seen from the inside, these appear as five pairs of transversely elongated openings, each bounded by a thickened framework somewhat complicated at the outer (proximal) ends. These openings allow muscles from above to enter the basal segments of the legs throughout their entire extent. The transverse areas between the frames of the appendages are covered by membrane which is thin but somewhat chitinous. Apparently the basal segments of the legs have but little motion in any direction.

Chelicerae are attached near the median line back of the proximal ends of the second, and about on a line with those of the third appendages. Two long thickenings, incurved at the posterior end, support them. These might leave impressions on casts of the interior in the fossil state. Near their anterior ends, on the median line, is a small subcircular thickening, the *subfrontal selerite*. Between the mesial ends of the coxae of second pair of appendages, and just in front of the mouth is the *camerosome*, a narrow, highly convex, keeled plate. The bases of the chelicerae embrace its anterior moiety. Behind the mouth is another plate, narrow in front and wide behind, the *promesosternite*. This and the camerosome may represent the metastoma and hypostoma of the trilobite.

Class ARACHNIDA

Subclass MEROSTOMATA Woodward

Order XIPHOSURA Gronovius

Suborder SYNXIPHOSURA Packard

Xiphosura with all the segments of the trunk freely movable.

This suborder contains many genera about which little is known. The only ones which seem to be close relatives of the later limuloids are Neolimulus Woodward, from the Upper Silurian, and Weinbergina R. and E. Richter, from the Lower Devonian.

Suborder LIMULADA R. and E. Richter

Xiphosura with some or all of the trunk segments anchylosed. Prosoma with opthalmic ridges, at least at the posterior margin.

This is only a part of the original definition of the suborder[1], but it seems inadvisable, in our present state of ignorance, to include statements about the appendages or other morphological features as yet unknown. For example, the Richters included as the first characteristic in their diagnosis "Prosoma mit verlangerten Hinterecken," which is not true of any member of a new family to be described in this paper.

The second sentence of the present definition is introduced in view of the fact that anchylosis of segments is a common feature of various lines of arthropods, and it is not unlikely that it took place in various groups of the Synxiphosura.

Superfamily BELINURACEA nov.

Limulada with some of the anterior segments of the trunk movable, two or more at the posterior end anchylosed.

Eller has recently reviewed the members of the genus Belinurus and assembled figures of most of the described species.[2] Without actual material it would be unsafe to make a revision of the group, but it is obvious that more than one genus is involved. Judging from the terminal portion of the axial lobe of the thoracetron, *Belinurus metschetnensis* and *B. iswarinensis* Tchernechev are almost certainly species of Euproöps, and one suspects that *B. stepanovi* of the same author is another. Tchernechev may have been using Packard's totally erroneous definition of Belinurus. It would be difficult for anyone to write a paper with more mistakes to the page and plate than that of Packard,[3] and unfortunately it is so beautifully illustrated that it is bound to cause confusion for years to come.

Turning to the other species of Belinurus, the figures seem to indicate that the genus contains prototypes of the two sorts of prosomae present in the Euproöpacea and the Limulacea. Most of the species have the posterior branch of the opthalmic ridge practically parallel to the axis of the prosoma, extending straight forward to the eye.

[1] Senckenbergiana., **2**, 1929, p. 206.
[2] Ann. Carnegie Mus., **27**, 1938, pp. 129–150, pls. 9–14.
[3] Mem. Nat. Acad. Sci., **3**, 1886.

This group includes *Belinurus reginae* Baily, *B. arcuatus* Baily, *B. concinnus* Dix and Pringle, *B. grandaevus* Jones and Woodward, *B. alleghanyensis* Eller, and some specimens which have been referred to the type of the genus, *B. bellulus* Koenig (Eller's pl. X, figs, 7, 8). This is the type of opthalmic ridge characteristic of the Limulacea.

Other species, not so numerous, have the type of ridge characteristic of the Euproöpacea, that is, a curved opthalmic ridge bearing outward to the eye. This is probably characteristic of the true Belinurus for it is shown in Koenig's original figure of the genotype (Petrificata Derbiensia, 1809) and in specimens figured later by other writers (Eller's pl. X, figs, 3, 4, 6). It is present also in *Belinurus truemani* Dix and Pringle, *B. morgani* Dix and Pringle, and *B. pustulosus* Dix and Pringle.

It is also important to note that the species with the parallel opthalmic ridges have, on the whole, triangular trunks, whereas those with curved ones are of a much more rounded type. It seems probable that the Devonian ancestor of the Limulacea was not unlike *B. alleghaniensis* and that the Devonian ancestor of the Euproöpacea was more like the Carboniferous *B. truemani*.

Since these two lines are so clearly marked, it may be helpful to make a new genus for the forms with parallel opthalmic ridges.

Family BELINURIDAE PACKARD (restricted)

Diagnosis, for the present, the same as for the super family.

Genus Belinurus Koenig

Belinuridae with the posterior portions of the opthalmic ridges curved and directed outward. Trunk rounded, ovoid to semicircular in outline, with two or more anchylosed segments at the posterior end. Genotype, *Belinurus bellulus* Koenig.

Genus KOENIGIELLA genus nov.

Belinuridae with the posterior portions of the opthalmic ridges parallel. Trunk subtriangular in outline, with two or more of the segments anchylosed at the posterior end. Genotype, *Belinurus reginae* Baily.

Species definitely assigned to this genus are *Koenigiella alleghaniensis* (Eller), *K. reginae* (Baily), *K. arcuata* (Baily), and *K. koenigiana* (Woodward). The others mentioned above as being of this type

probably belong here, but in the absence of actual material it would be unsafe to make a definite decision. I would however, venture to predict that *Prestwichia randalli* Beecher from the Upper Devonian will prove to belong to this family and possibly to this genus when the trunk is found.

Superfamily EUPROÖPACEA nov.

Limulada with broad, rounded thoracetron, with or without lateral spines; posterior portions of opthalmic ridges, if present, turn outward to the eyes.

This superfamily is proposed to include a branch of the Limulada which seems not to have survived the Paleozoic. The thoracetron approximates the shape of a circle, truncated where connected to the prosoma. In a specialized family described below, (Liomesaspidae) the lateral spines are lost, along with more or less of the longitudinal and transverse furrows, producing relatively smooth forms. This is the same sort of "smoothing out" that is so characteristic a feature of various phyletic lineages of trilobites.

In the main family, Euproöpidae, the opthalmic ridges have a typical course, a curved posterior portion turning outward from the posterior margin forward to the eye, then forward and inward, to join the anterior end of the cardiac lobe. This course is that seen in many species of belinurids, and differs from that in the Limulacea, in which the posterior portion of the ridge extends straight forward or slightly inward to reach the eye. This same course is characteristic of such of the Liomesaspidae as retain the ridges, but the dorsal surface of the prosoma in the Elleriidae and Prolimulidae is unknown.

A characteristic feature of the Euproöpidae and Liomesaspidae, but not the Elleriidae, is the nature of the posterior end of the axial lobe of the thoracetron. In this region there are no transverse furrows, but the surface rises into a high boss with a low conical spine at the top. Behind the spine the surface drops abruptly in a concave slope to a low, smooth posterior area. Some specimens show an impressed line on the back slope of the boss, rising to an inverted A just behind the spine.

There is no indication of articulated spines on the thoracetron of any member of this superfamily, or any suggestion of the trapezoidal shape of the thoracetron of the Limulacea. It seems to have been an evolutionary line entirely different from that which led to modern Limulus.

Family EUPROOPIDAE Eller

Euproöpacea with dorsal furrows on the prosoma and marginal spines on the thoracetron.

Genus Prestwichianella H. Woodward

Limulus Prestwich, Trans. Geol. Soc., 2d ser., 1840, vol. 5, pl. 41, figs. 5, 6.—*Belinurus* Baily, Ann. and Mag. Nat. Hist., 1863, ser. 3, vol. 11, p. 113.—*Prestwichia* H. Woodward, Quart. Jour. Geol. Soc. London, 1867, vol. 23, p. 32, pl. 1, fig. 2; Paleontological Soc., London, 1878, p. 244, pl. 31, fig. 5; Geol. Magazine, 1868, vol. 5, p. 2. Meek and Worthen, Pal. Illinois, 1868, vol. 3, p. 547, fig. B, p. 548. Packard, Nat. Acad. of Sci., Mem. 16, 1886, p. 148, fig. 10—Dunbar, Am. Jour. Sci., 1923, ser. 3, vol. 5, p. 451.—*Prestwichinella*, H. Woodward, Geol. Mag., 1918, ser. 6, vol. 5, p. 469. Dix and Pringle, Summary of Progress Geol. Sur. Great Britain for 1928, 1929, p. 92, 101. Pruvost, Mem. du Musée Roy. d'Hist. Nat. Belgique, No. 44, 1930, p. 200.

Euproöpidae with a short, wide cardiopthalmic area, subdivided into four parts. Genotype, *Limulus rotundatus* Prestwich.

Euproöps and Prestwichia were described in the same year, 1867, and no satisfactory distinction has ever been drawn between them. Meek, in his original description of Euproöps said: "From Prestwichia with which it more nearly agrees in general form as well as in its anchylosed segments, it differs in having the area enclosed by the eye-ridge (glabella) comparatively small, and of a quadrangular form, with the eyes situated far forward on its anterior lateral angles." He also called attention to the fact that the cardiopthalmic area of Prestwichia was proportionately larger than in Euproöps, and was transversely elliptical rather than quadrangular in outline.

Henry Woodward long refused to accept Euproöps as a distinct genus, which is not surprising, for after his original definition of Prestwichia he cited as typical species, first, *Limulus anthrax* Prestwich, and second, *L. rotundatus* Prestwich. Fifty-one years later, in 1918, he admitted that *L. anthrax* was a Euproöps, hence it is evident that the original definition included both genera. As the first species mentioned under the generic name Prestwichia, *P. anthrax* might have been selected as the genotype, in which case Euproöps would have become a synonym. Fortunately it was not, and when in 1918, Woodward learned that the term Prestiwichia had been used before 1867, he designated *Prestwichia rotundata* as the type of a genus under the new designation Prestwichianella. On this occasion he stated of *P.*

rotundata: "the glabella [cardiopthalmic area] is divided along the center by the axial furrow, and by two other slightly diverging parallel lines on either of the axis, reaching nearly half-way to the frontal border, where they are arcaded, forming a raised confluent line in front of the glabella. The circular line seen outside the border of the glabella may indicate the impression of the line of the broad incurved undermargin of the head-shield." The first part of this statement is incomprehensible to the writer, for he has seen no other xiphosuran with a median furrow on the cardiac lobe. It is, however, quoted by Dix and Pringle in 1929, apparently with approval, although the new species which they describe is said to have a narrow *raised* median ridge. According to Dix and Pringle, the eyes of Prestwichianella are situated at the anterior lateral angles of the cardiopthalmic area, as in Euproöps. Woodward made no definite statement as to the position of the eyes in *P. rotundata* except that they are on the raised lateral border, nor are they shown in any figure.

Dix and Pringle were not able to find any further specimens which they could positively identify as *P. rotundata*, hence it is necessary to draw our conclusions as to the generic characteristics from the type. The original specimen in the Prestwich collection has been properly figured twice, once by that author, and again by Woodward (1878). A diagramatic figure by Woodward (1867) has been widely copied, but is incorrect in many particulars. Inaccurate as this figure is, it does bring out what seems to be a unique characteristic of *P. rotundata*, that is, that the cardiopthalmic area is quadra-, not tripartite. This is in itself a sufficient generic characteristic, and may for the present stand as the most important feature.

Pruvost identified *P. rotundata* in the Westphalian of northern France and adjacent portions of Belgium, but his figure does not show the critical area of the prosoma. He reported the presence of the species not only in continental deposits, but also in marine beds associated with *Productus carbonarius*.

Genus EUPROOPS Meek

Bellinurus Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 44. Geol. Survey Illinois, vol. 2, 1866, p. 395.

Prestwichia Meek, Am. Jour. Sci., ser. 2, vol. 43, 1867, p. 257, Packard, Nat. Acad. Sci., vol. 3, mem. 16, 1886, p. 146, 148, 150. Bergeron, Bull. Soc. Geol. France, ser. 3, vol. 21, 1893, p. 342; vol. 23, 1895, p. 480. Zalessky, Bull. Comité Geol. de St. Pétersbourg, vol. 26, 1907, p. 423. Bolton, Trans. Manchester Geol. Soc., vol. 34, 1915. Pruvost, Mem. Carte Geol. de France, 1919, p. 333. Tchernechev, Bull. Comité Geol. de Leningrad, vol. 47, 1928, p. 526. *Euproöps* Meek, Am. Jour. Sci., ser. 2, vol. 43, 1867, p. 394; Geol. Mag. vol. 4, 1867, p. 320. H. Woodward, Geol. Mag. 1868, vol. 5, p. 2. Meek and Worthen, Geol. Survey Illinois, vol. 3, 1868, p. 547, White, Geol. and Nat. Hist. Indiana, 13th Ann. Rept. for 1883, (1884), p. 170. Packard, Am. Naturalist, vol. 19, 1885, p. 292. Ebert, Jahrb. d, geolog. Landesanst, 1889, p. 218. Baldwin, Geol. Mag., Dec. 5, vol. 8, 1911, p. 75. H. Woodward, Geol. Mag. n.s., Dec. 6, vol. 5, 1918, p. 465. Dix and Pringle, Summary of Progress, Geological Survey, Great Britain, for 1928 (1929), pt. 2, p. 103. Pruvost, Mem. du Musée Roy. d'Hist. Nat. Belgique, no. 44, 1940, p. 201. Kobayashi, Jap. Jour. Geol. and Geog. Tokyo, vol. 10, 1933, p. 178. Willard and Jones, Proc. Penna. Acad. Sci., vol. 35, 1935, p. 127. Eller, Ann. Carnegie Mus., vol. 27, 1938, p. 152. *Prestwichianella*, Tchernechev, Comité Geol. du Leningrad, vol. 46, 1927, no. 5, p. 648, 653.—*Anthracopeltis*, Boulay, Ann. Soc. Scientifique, Bruxelles, 4 anneé, 1880, p. 277.

Euproöpidae with a tripartite cardiopthalmic area, the cardiac lobe bordered by dorsal furrows. Intergenal spines present. Genotype, *Bellinurus danae* Meek and Worthen.

Euproöps danae (Meek and Worthen)

Bellinurus danae Meek and Worthen, Proc. Acad. Nat. Sci., Philadelphia, 1865, p. 44; Illinois Geol. Survey, vol. 2, 1866, p. 395, pl. 32, fig. 2, 2a.

Prestwichia danae Meek, Am. Jour. Sci., ser. 2, vol. 43, 1867, p. 257. Packard, Nat. Acad. Sci., vol. 3, 1886, Mem. 16, p. 146, pl. 5, figs. 3, 3a; pl. 6, figs. 1, 1a, 2, 2a.

Euproöps danae Meek. Am. Jour. Sci. Ser. 2, vol. 43, 1867, p. 395; Geol. Mag., vol. 4, 1867, p. 320. H. Woodward, Geol. Mag. vol. 5, 1868, p. 2. Meek and Worthen, Geol. Sur. Illinois, vol. 3, 1868, p. 547, text fig. A. White, Geol. & Nat. Hist. Sur. Indiana, 13th Ann. Rept. for 1883 (1885), p. 170, pl. 39, fig. 1.

Euproöps colletti White, Geol. Nat. Hist. Sur. Indiana, 13th Ann. Rept. for 1883 (1885), p. 172, pl. 39, fig. 2.

For bibliography of numerous European specimens which have been referred to this species, see Pruvost, Mem. du Musée Roy. d'Hist. Nat. Belgique, no. 44, 1930, p. 203. Without specimens, it is impossible to say whether or not any of them are conspecific with the American forms.

This species has been so well described that no formal diagnosis is necessary. Although specimens are common, few are really well preserved. The test appears to have been but slightly if at all impregnated with calcium carbonate, perhaps because of the freshwater environment. Because of its tenuous nature the shell wrinkled easily, and I have seen no individual with the prosoma undistorted. The thoracetron, however, is in many cases, rather well preserved. The best figures are the photographs in Packard's article (specimen in U. S. Nat. Mus. no. 38, 954).

The prosoma is from 2.5 to 3 times as wide, at the bases of the genal spines, as it is long. The cardiopthalmic area is outlined by narrow ridges which are concave outward back of the eyes, convex forward in front of them, forming a double arch supported by the narrow anterior prolongation of the cardiac lobe. The eyes are a little further apart than are the posterior ends of the opthalmic ridges, and the cardiac lobe is about one-fourth shorter than the distance between the eyes. As pointed out by Meek and Worthen in their original description, the cardiac lobe tapers rapidly forward, the anterior third being narrow, almost linear. The better preserved specimens show a transverse bar at the point where the taper ends.

An exceptional specimen (Yale Univ. Mus. No. 16,909) shows the paired ocelli at the anterior end of the cardiac lobe, and three pairs of faintly impressed crescentic pits in the dorsal furrows. The first of these is immediately behind the transverse bar just mentioned, the last at the base of the cardiac lobe. The intermediate ones are exceedingly faint. These are doubtless scars of attachment of coxal muscles.

The thoracetron is divided by dorsal furrows into a median and lateral lobes. The furrows are almost parallel but diverge near the posterior end to embrace a blunt boss which is excavated behind. Including this boss, there are six rings on the axial lobe; the first and third bear rounded tubercles; the boss has a short thornlike spine. In the dorsal furrows there are six pairs of depressions, indicating six pairs of entopopheses like those of modern Limulus. The first pair is beside the first ring, the last ones just in front of the boss. On the front of the boss, inside the furrows, is a pair of shallow conical pits.

On the lateral lobes, each segment is set off by a narrow ridge at its

posterior margin. Six of these are extended across the flattened border into long spines directed radially backward. A seventh segment is indicated by short spines which extend backward close to the telson. Compared with Limulus, there is little space between the posterior appendages and the telson. The margins show no indications of articulated spines.

Few specimens retain the entire telson, which is much longer than is generally supposed. On the only individual on which it appears to be complete (M.C.Z. 4686, obverse), it is 26 mm. long. The thoracetron to which it is attached is 17 mm. long, and the prosoma 19 mm.

Young specimens differ in some respects from the adult. The cardiac lobe tapers regularly forward instead of contracting to a narrow ridge at the half-length, and the thoracetron is proportionately wider, with shorter, much less strongly developed spines. That the young, at least, had the power of enrollment, is shown by one specimen (M.C.Z. 4673).

Measurements. The following are the measurements of the type given by Meek and Worthen in their original article: "Entire length from the extremity of the caudal segment to the anterior margin of the cephalo-thorax, about 1.90 inches. Length of cephalo-thorax, 0.57 inch, breadth of do. to the extremities of the postero-lateral spines, 1.70 inches; length of area included within the ocular ridge, 0.50 inch; greatest breadth of do. (which is the distance between the eyes,) 0.60 inch. Length of abdomen, 0.65 inch; breadth of do., exclusive of the flattened margin, 0.94 inch, including it, 1.06 inch; breadth of mesial lobe, 0.23 inch; length of caudal segment, about 0.60 inch."

Formation and locality. This is the most common xiphosuran in the nodules in the Francis Creek shale in the Mazon Creek region in Grundy and Wills counties, Illinois. *Euproops colletti*, described by White from a poorly preserved specimen from Durkee's Ferry, Vigo County, Indiana, probably belongs to this species.

Euproöps thompsoni spec. nov.

Figs. 1, 2

Study of collections of Euproöps from the vicinity of Mazon Creek shows that the common forms represent two species. The chief difference is in the proportions of the prosoma. *E. danae* is a wide headed form, the width at the bases of the genal spines being from 2.5 to 3 times the length. The other species is relatively more narrow headed,

with a definite ratio of width to length of two to one. Specimens of this kind are rather common.

It might seem that the difference in proportion could be due to the state of preservation, that is, that the flattened specimens would show a proportionately wider prosoma than an uncrushed one. One does find some variations in measurements due to this cause, but I have found in the Harvard and Yale collections both young and full grown flattened and fully convex specimens of both the wide and the narrow headed forms, and am convinced that the difference is not one of condition of preservation. The prosomas, if well preserved, can easily be distinguished by the difference in the form of the cardiac lobe.

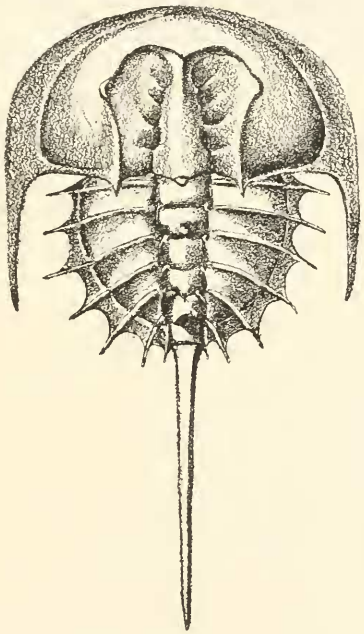


Fig. 1. *Euproöps thompsoni* Raymond—a composite figure to show the writer's interpretation of the structure. The prosoma is based on a not-quite-fullgrown individual (M.C.Z. no. 4683) and the remainder on the holotype (M.C.Z. no. 4669). x 2.

The prosoma, neglecting the genal spines, is semi-circular in outline, moderately convex in the adult, highly vaulted in the halfgrown

individuals. The cardiac lobe differs from that of *E. danae* in its uniform taper forward: in some specimens there is expansion in front of the mid-length. Since the prosoma is proportionately longer, the cardiopthalmic area appears to be somewhat smaller than in *E. danae.*

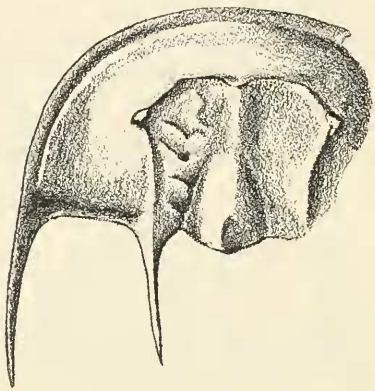


Fig. 2. *Euproöps thompsoni* Raymond. The prosoma of a young individual with especially well preserved genal and opthalmic spines. x 3. M.C.Z. no. 4684.

Young specimens

Several young individuals in the collection are unusually well preserved. The prosoma is more highly convex than in the adult, and the cardiac lobe has less anterior expansion. There is a short spine at the posterior end of the cardiac lobe, and a long one at the end of each opthalmic ridge; each spine has a narrow dorsal carina. The intra-opthalmic areas, between the cardiac lobe and the opthalmic ridges have shallow transverse furrows, limiting six pairs of ill-defined lobes. The genal spines of these uncrushed specimens are directed almost straight backward suggesting that the flare so common in the adults is due to flattening. Two specimens are casts of the under side, and show in front of the cardiac lobe a longitudinal depression (cardiac furrow) occupied by the anterior ventral portion of the stomach. The doublure is narrow, with what appears to be a median plate. The specimen also shows the proximal segments of three of the appendages. They indicate that the coxae were short and attached just outside the dorsal furrows.

The thoracetron is proportionately shorter than in the adult, but has 6 pairs of ribs, 5 rings on the cardiac lobe, and 6 pairs of entopophyses.

Measurements. The holotype (M.C.Z. 4669), is 57 mm. long, including the telson. The prosoma is 20 mm. long, 38 mms. wide at bases of genal spines: the cardiac lobe is 11 mm. long, the width between the eyes is 14 mm., and the posterior ends of the opthalmic ridges are 14 mm. apart. The thoracetron is about 20 mm. long, and about 24 mm. in greatest width. The telson is 23 mm. long, but is incomplete at the posterior end. The prosoma of a young specimen (M.C.Z. 4682), is 10 mm. long, 21 mm. wide; the cardiac lobe is 6.5 mm. long, the width between the eyes 9 mm., and the posterior ends of the opthalmic ridges are 7 mm. apart. The thoracetron of another young specimen (M.C.Z. 4670), is 8 mm. long and 12 mm. wide. Apparently the thoracetron increases more rapidly in length than in width during growth.

Formation and locality. The specimens here figured are from the Francis Creek shale of the Carbondale series at the Wilmington Strip Mine, Wills Co., Illinois. They were donated by Mr. Frederick Thompson, for whom the species is named. The holotype is M.C.Z. 4669 and the paratypes M.C.Z. 4670, 4676, 4682, 4683, and 4684.

Euproöps darrahi spec. nov.

Pl. 2, fig. 4

The specimen on which this species is founded is unquestionably a young Euproöps of the *E. danae* type, the prosoma being about 2.5 times as wide as long. It differs from *E. danae*, however, in that the cardiopthalmic area and the cardiac lobe are proportionally longer, and in that the thoracetron is proportionately considerably larger.

The specimen appears to show the interior of the test, and 6 pairs of entopophyses are well shown on the thoracetron. Because it is a young individual, the marginal spines are short. The cardiac lobe tapers gradually forward from the posterior to the anterior end, a characteristic of the young of *E. danae* and the adult of *E. thompsoni*.

Dimensions. Length of holotype without telson, 10 mm.; length of prosoma, 5 mm., width at bases of genal spines, 13 mm.; length of cardiac lobe, 4 mm.; length of thoracetron, 5 mm., width, about 9.5 mm.

Formation and locality. The holotype (M.C.Z. 4691) was found in the Mason shale beneath the Brush Creek limestone in the lower part of the Conemaugh, at Fair Oaks, Ambridge, Pennsylvania. It was collected and donated by Mr. W. C. Darrah, for whom it is named.

Euproöps laevicula spec. nov.

Fig. 3

The prosoma of this species is like that of *E. thompsoni;* but the thoracetron differs in having the lateral lobes almost smooth, with only the faintest traces of transverse ridges. The axial lobe has only

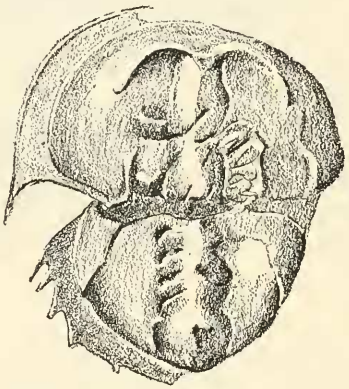


Fig. 3. *Euproöps laevicula* Raymond. The holotype. x 3. (Yale Univ. Mus., no. 16912).

faint transverse furrows, and although there are nodes on the third and last rings they are less well developed than in other species. There appears to be an extra pair of lateral spines at the anterior end of the thoracetron, a condition which may have some significance in connection with the position of the articulation between the prosoma and thoracetron.

Dimensions. The holotype, a young specimen, has a prosoma 8.5 mm. long and about 18 mm. wide. The thoracetron is 7 mm. long and about 14 mm. wide.

Formation and locality. From the Francis Creek shale at Mazon Creek, Grundy Co., Illinois. The holotype is 16912 and the paratype 16916 in the Yale University Museum.

Euproöps laticephalus spec. nov.

Fig. 4

This species is characterized by the great width of the prosoma and the relatively short wide cardiopthalmic area. It differs in the latter respect from all the other American species. The cardiac lobe is like that of *E. danae*, that is, it tapers abruptly forward and is then continued as a narrow median ridge. There is a small median pustule

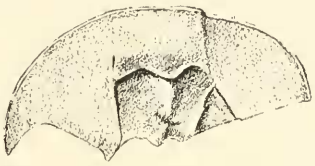


Fig. 4. *Euproöps laticephalus* Raymond. The holotype. Natural size.

at the posterior end. Only the proximal portion of one genal spine is preserved, but it indicates that the full length was considerable.

Euproöps islwyni Dix and Pringle[4] has the same broad form and short wide cardiopthalmic area. It may be related.

Dimensions. The prosoma is 17 mm. long and about 40 mm. wide. The cardiopthalmic area is 9 mm. long on the median line, 11 mm. wide at the posterior margin, and the width between the eyes is 13 mm.

The species is probably most closely allied to *E. danae*, differing in having a shorter cardiopthalmic area.

Formation and locality. The holotype was collected many years ago by Leo Lesquereux from roof shale of the Salem coal, high in the Pennsylvanian, near Pottsville, Penna. W. C. Darrah has identified the following plants on the same slab: *Asterophyllites* sp., *Sphenophyllum filiculme* Fontaine and White, *Pecopteris arborescens*, Schlotheim, *P. feminaeformis* Schlotheim, *Mariopteris ribeyroni* Zeiller, and *Neuropteris plicata* Brongniart. This flora is, Mr. Darrah informs me, characteristic of the lower beds of the Monongahela series of the Pennsylvanian. The holotype is M.C.Z. 4692.

Euproöps longispina Packard

Euproöps longispina Packard, Am. Naturalist, vol. 19, 1885, p. 292.
Prestwichia longispina Packard, Nat. Acad. Science, Mem. vol. 3, 1886, p. 147, pl. 5, fig. 4, (not pl. 6, fig. 3).

[4] Geol. Survey of Great Britain, Summary of Progress for 1928, 1929, p. 107, fig. 12.

This species was badly described and figured by Packard. Dr. Bassler has been kind enough to send me a cast of the specimen on which it was founded. In this case there is a real holotype, (U. S. Nat. Mus., 38, 857), for the author definitely stated that the species was based on this individual.

The general characteristics of the species are those of *E. danae*, the prosoma being short and wide. The direction of the opthalmic ridges is the same as in that species, but the cardiac lobe tapers gradually forward as in *E. thompsoni*. Packard's figure of the prosoma may be entirely ignored, for the cardiopthalmic area does not taper forward, and the genal spines are not particularly long.

The thoracetron is like that shown by Packard only in the length of the marginal spines. The cardiac lobe is definitely outlined, has five rings in front of the large posterior one, and there are the usual elevated ribs on the plural lobes.

This species differs from *Euproöps danae* in having much longer spines on the thoracetron; from *E. thompsoni* in this respect and in the wider prosoma; from *E. laticephalus* in having a longer cardiopthalmic area, and from *E. packardi* and *E. laevicula* in having more distinct ribs in the pleural lobes, as well as in the long spines, which are the most distinctive feature.

Formation and locality. This specimen is from the shale over Coal E, (Mammoth vein), at the Butler mine, Pittston, Pennsylvania, and hence is presumably of Upper Allegheny age. Holotype in the U. S. National Museum, no. 38,857.

Euproöps spec. ind.

Prestwichia longispina Packard (partim), Nat. Acad. Sciences, Mem. vol. 3, 1886, p. 147, pl. 6, fig. 3.

So far as one can judge, this rather poorly preserved specimen belongs to a species closely allied to *E. thompsoni*. As mentioned in the discussion of *E. longispina* it was mentioned by Packard as an "additional specimen," and so should not be listed as a cotype as it has been in the U. S. National Museum.

Formation and locality. The exact zone from which this specimen was obtained is not known, as it was found on the dump at the Oakwood colliery, Wilkes-Barre, Penna. It is supposed to have come from Upper Allegheny or Lower Conemaugh strata.

Euproöps amiae H. Woodward

Euproöps Amiae H. Woodward, Geol. Magazine, ser. 6, vol. 5, 1918, p. 465, figs. 2, 3, 4.

Euproöps amiae is closely allied to both *E. danae* and *E. thompsoni*. The specimen is small, the prosoma only 12 mm. long, and hence probably not adult. The width at the bases of the genal spines is 29 mm., nearly 2.5 times the length, hence the proportions suggest those of *E. danae*. The species differs from both *E. danae* and *E. thompsoni*, however, in having a wider cardiac lobe.

The original specimens were from the Glace Bay mines, Cape Breton, Nova Scotia.

Euproöps packardi Willard and Jones

Euproöps packardi Willard and Jones, Penn. Acad. Sci., Proc. vol. 9, 1935, p. 127, figs. 1, 2.

This species was founded on what appears to be a young individual of the *E. danae* type. It has a wide prosoma, showing relationship to *E. danae*, and a short wide thoracetron indicating that it is young (the length of the specimen without telson is 17.5 mm.). The cardiac lobe is particularly like that of *E. danae* in coming to a point at about the half length, and being continued as a narrow ridge. For details of the prosoma the photograph rather than the drawing should be consulted.

The real difference from *E. danae* is in the thoracetron. The ridges which indicate the segmentation do not cross the margins onto the spines, nor do they reach the axial lobe. In this respect the species is more closely allied to *E. laevicula*, described above.

The specimen was collected from a culm pile at the Baltimore mines near Parsons, Penna., and is probably of Allegheny age.

A specimen in the Lesquereux collection (M.C.Z. 4693) from an undetermined zone "Low in the Coal measures" at or near Wilkes-Barre, Penna., may be an adult of *E. packardi*. It is preserved in pyrite coated with carbonaceous mud, and is exposed from the inside. It agrees with *E. packardi* in having incomplete ribs on the pleural lobes of the thoracetron, and in proportions. The prosoma is 12 mm. long and about 30 mm., wide, and the cardiopthalmic area has a mid-length of 8.5 mm. The thoracetron is 9.5 mm. long and about 20 mm. wide, hence proportionally a trifle narrower than that of the younger individual which is the holotype.

Euproöps lacoei (Packard)

Belinurus lacoei Packard. Am. Naturalist, vol. 19, 1885, p. 292: Nat. Acad. Sciences, Mem. vol. 3, 1886, p. 149, pl. 5, fig. 5.

As Dunbar has already pointed out, this species cannot possibly be included in Belinurus. It is a Euproöps, closely related to *E. danae*.

Schuchert, in cataloging the types in the United States National Museum[1] remarked of this species: "Probably the same as *Prestwichia danae*. Probably a sexual difference." Even before I saw this statement I had inferred from the figure that *Belinurus lacoei* was a young *Euproöps danae*, but curiosity about the number of segments in the thoracetron led me to seek information about the types. Fortunately they are in the National Museum, and Dr. Ray S. Bassler has supplied me with casts of all of them.

Packard listed as "types," specimens in Mr. Lacoe's collection numbered 210^{hl}, 210^{y}, 210^{wx}, 212^{ab}, and 213^{a}. All were, therefore, cotypes. In the Catalogue already referred to, however, Schuchert listed only one of them, no. 210^{y}, and designated it as the holotype. His reason for doing this is probably explained by the label now with the specimen, and supposed to be in Mr. Lacoe's handwriting, stating that it is the original of Packard's plate 5, figure 5.

Without the label, no one would have suspected that this was the type, for the middle portion of the prosoma is entirely broken away, no traces of opthalmic ridges, eyes, or cardiac lobe remaining. The damage is so great that it is difficult to measure the length, but it is about 10 mm. Since the figure is labeled as twice natural size, this measurement checks. The width at the bases of the genal spines is about 24 mm. which is only a little less than that shown by the figure. The thoracetron is poorly preserved, is shorter and wider than in the figure, and the cardiac lobe so damaged that the number of rings can not be surely counted. There is no reason to think that there are more than in *E. danae*. The telson is not completely exposed, the distal portion being under the matrix. The part shown is 12 mm. long, whereas, according to the figure, it should be 30 mm. long. From the part visible and the rate of taper, a total of 20 mm. would be the maximum length to be expected. In other words, the "holotype" shows none of the characteristics of the figure except correspondence in length of the prosoma.

[1] U. S. Nat. Mus. Bull. 53, 1905, p. 96.

There is, however, a question whether this specimen, although it was the basis of the figure, was really the most important of the cotypes, for Packard's measurements of what he calls the "best preserved specimen" are those of a much smaller individual, with the prosoma and thoracetron together 15 mm. long. There is no individual among the cotypes of exactly this size, and but one which closely approximates it. This is the one numbered 210^{hl}, which occupies first place in Packard's list. The prosoma and thoracetron are 14 mm. long in this specimen. The prosoma is 7.5 mm. long and 17.5 mm. wide, and the telson, which is incomplete, is 11 mm. long. The entire length might have been as much as 14 or 15 mm., or about the same length as the body. In all probability this is the measured individual, but it is so poorly preserved that it could not have furnished the information for the figure. The cardiac lobe of the thoracetron is especially poor, and the number of segments cannot be counted.

Packard's figure is admittedly composite, but the types justify none of its important characteristics. Two of them have already been discussed. Lacoe's no. 210^{wx} is, perhaps, the best preserved of the lot. It has the same sort of cardiac lobe on the prosoma as *E. danae*, and the same number of rings on the thoracetron, but the lateral lobes of that shield are about as smooth as in *E. laevicula*. No. 212^{ab} has the same sort of thoracetron, and a badly damaged prosoma. Neither shows a great deal of the telson. No. 213^{a} is a small, badly preserved individual which may be a specimen of *Liomesaspis laevis*. In addition to these, the National Museum has another specimen not mentioned by Packard, Lacoe's No. 212^{c} (U. S. Nat. Mus. no. 38,861). This is much better preserved than any of the cotypes, but is a typical young *E. danae*, with the cardiac lobe continued forward from the midlength as a narrow ridge, and typical thoracetron. The prosoma is 10 mm. long and 25 mm. wide.

It seems then, that *Euproöps lacoei* was founded upon a misinterpretation of five poorly preserved specimens, the least obscure of which is the one Schuchert designated as the holotype. Such evidence as exists indicates that it is a young individual of *E. danae*, and the name may as well be dropped.

Formation and locality. All the specimens are said to have been found at Mazon Creek, Grundy County, Illinois.

Genus ANACONTIUM genus nov.

Euproöpidae with tripartite cardiopthalmic area, but without intergenal spines. Type, *Anacontium carpenteri*, spec. nov.

ANACONTIUM CARPENTERI spec. nov.

Fig. 5

Prosoma rounded in outline, less than twice as wide as long, evenly convex. The genal spines are small, vestigal. The cardiac lobe is relatively short, wide at the posterior end, tapering forward, ending in a prominence behind the point at which the preocular ridges meet. The dorsal furrows are shallow but distinct. The intra-opthalmic areas

Fig. 5. *Anacontium carpenteri* Raymond. x 4.
Fig. 6. *Anacontium brevis* Raymond. x 4.

show no furrows. The eyes are small, well forward and far apart, so that the cardiopthalmic area occupies a large portion of the prosoma. The genal spines are minute, and probably would not be seen on poorly preserved specimens. The posterior margin of the prosoma is turned down vertically, as in modern Limulus.

Measurements. The holotype (prosoma) is 7 mm. long, 12 mm. wide; the width between the eyes is 7.50 mm. and the posterior ends of the opthalmic ridges are 5.75 mm. apart. The cardiac lobe is 4.5 mm. long, and 3 mm. wide at the posterior end. The cardiopthalmic area is 5 mm. long, on the median line. The paratype (prosoma) is 5 mm. long, about 9 mm. wide and the width between the eyes is 5.50 mm.

Formation and locality. Two specimens of the prosoma were collected from the Wellington formation on the southwest quarter of the northwest quarter of section 2 of township 21 north, range 1 west, in Noble County, Oklahoma, where they were associated with numerous specimens of Conchostraca and insects. The holotype is M.C.Z. 4724, and the paratype M.C.Z. 4725. It is named for Professor F. M. Carpenter who found the specimens, and whose studies and collections have greatly enlarged our knowledge of Permian arthropodan faunas.

ANACONTIUM BREVIS spec. nov.

Fig. 6

This species differs from the preceding in having well developed genal spines, the eyes further forward, and particularly in the unusually short cardiac lobe. It might at first sight be confused with *Paleolimulus avitus*, because of the lack of intergenal spines and the general configuration of the prosoma. The postocular ridges curve inward, however, and the cardiac lobe is surprisingly short.

Measurements. The only known specimen is a prosoma which is not well preserved on the anterior margin, and in which the cardiac lobe has been crushed so that it is concave, instead of being convex. The measurements are therefore approximate.

Length, about 6.00 mm., width about 10.00 mm. The width between the eyes is 3.00 mm., the cardiac lobe is about 2.00 mm. long, and the point where the preocular ridges meet on the median line is 4.25 mm. from the posterior margin.

Formation and locality. The holotype, M.C.Z. 4726 was collected by Dr. F. M. Carpenter from the Wellington formation on the southwest quarter of the northwest quarter of section 2, township 21 north, range 1 west, in Noble County, Oklahoma.

Family ELLERIIDAE fam. nov.

Euproöpacea in which the primitive segmentation of the posterior portion of the axial lobe of the thoracetron is not obscured.

Genus ELLERIA genus nov.

ELLERIA MORANI (Eller)

Euproöps morani Eller. Ann. Carnegie Mus., vol. 27, 1938, p. 151, fig. 1.

Eller himself hesitated to make a new genus for this species, because only the thoracetron was known. However, it is not a Euproöps, and to assign it to that genus gives the impression that Euproöps occurs in the Devonian, which is misleading. I am therefore, naming it for Dr. Eller, and expressing the hope that he will find the prosoma which belongs with the species.

Elleria morani, as preserved, lacks the anterior part of the thoracetron but even though it had no more lateral area than is shown on the right-hand side of the original figure, it must have had two more rings on the axial lobe, making eight in all. Euproöps has five distinct rings

and six lateral ridges, one of them springing from the sides of the composite sixth ring. To make a homology, it would be necessary to postulate that the last three rings on *E. morani* corresponded with the anchylosed area at the posterior end of the axial lobe of Euproöps. Whatever the actual structure, it lacks the characteristic expression of the posterior end of the thoracetron of the Euproöpidae.

It is, however, an interesting and important specimen, being the oldest (Upper Devonian) xiphosuran with a fully anchylosed thoracetron. It is primitive, in that the median elements of all three of the prometasomatic segments remain distinct. In all probability there would be, in a complete specimen, eight rings on the axial lobe. The deep emargination at the posterior end may also be primitive, for Euproöps shows less of this feature and Liomesaspis none of it, and the latter is certainly a specialized genus.

Formation and locality. The holotype is from the Salamanca sandstone of the marine Upper Devonian at North Warren, Penna.

Family Liomesaspidae fam. nov.

Euproöpacea without true dorsal furrows on the prosoma or lateral spines on the thoracetron.

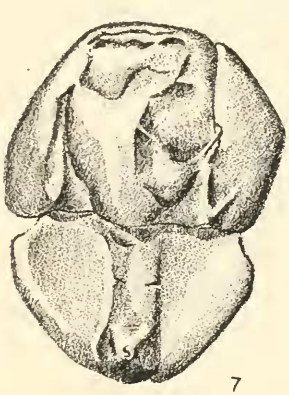
Genus Liomesaspis genus nov.

Liomesaspidae with rounded prosoma and without genal spines or defined cardiac lobe in the adult. Axial lobe of thoracetron clearly defined, but obscurely segmented. Genotype, *Liomesaspis laevis* spec. nov.

LIOMESASPIS LAEVIS spec. nov.

Figs. 7, 8, 9, 10

Prosoma evenly convex, from one-third to one-half wider than long, with a narrow flattened brim, only traces of which have been seen. The cardiac lobe is not outlined and the intraopthalmic area is



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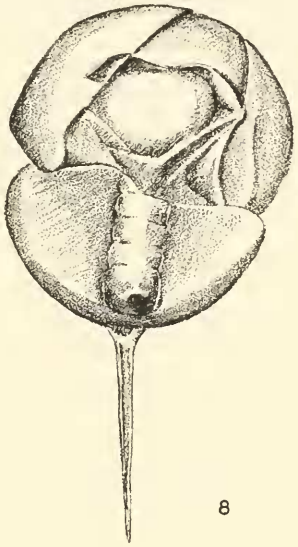

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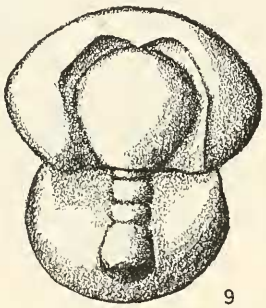
Fig. 7. *Liomesaspis laevis* Raymond. A much wrinkled specimen, with little trace of segmentation. x 3.

Fig. 8. The same species. A paratype showing more divisions of the cardiac lobe of the thoracetron and retaining the telson. Yale Univ. Mus., no. 16913. x 3.

nearly smooth, except for two divergent furrows which extend forward and outward from the posterior margin. On specimen M.C.Z. 4696 (fig. 7) the opthalmic ridges project as short spines at the posterior margin, but their full course can not be traced. Eyes are probably present, but no specimen is well enough preserved to give absolute proof of their position. They are probably a little in front of the middle, and widely separated. In front of the putative positions of the eyes, each opthalmic ridge arches around to a reëntrant on the median line, as in Euproöps. An immature specimen in the Yale University Museum (no. 16,914) shows small genal spines, placed well forward at the sides.

This is of interest since it indicates in these animals the same tendency as in the trilobites for genal spines to move forward and disappear.

The test of all specimens of the prosoma was evidently weak and thin, for all are considerably distorted and it is impossible to be sure of the original configuration. Since the specimens are small, this is in curious contrast to the condition in Euproöps, in which many of the young are well preserved, whereas the adults are distorted.



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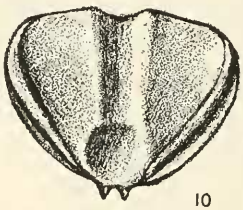

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Fig. 9. *Liomesaspis laevis* Raymond. An unusually well preserved individual, except for the telson. The holotype. x 2.5.

Fig. 10. The same species. A thoracetron, exposing the lower surface. At the posterior end are processes for articulation with the telson. Yale Univ. Mus., no. 16915. x 2.

The thoracetron, on the other hand, is commonly well preserved. The axial lobe is narrow, but expands at the posterior end where it rises into a high blunt spine. On the best preserved specimens this spine is excavated behind, having exactly the same shape as in *Euproöps danae*. The best preserved axial lobes show three complete rings and a half-ring in front of the terminal enlarged portion, but the transverse furrows are so shallow that the lobation is not conspicuous. As a rule it shows better on the cast of the interior of the shell than on the exterior. Three pairs of short linear grooves indicate the position of the entopophyses.

The lateral lobes are smooth, flat on the upper anterior surfaces, abruptly turned downward at the sides and back.

The telson is long and slender, slightly over two-fifths of the total length in the two specimens in which it has been possible to excavate the whole of it. Two processes extending backward from the underside of the thoracetron prevented its being turned downward, hence it was

of no value as a pushing organ, and it must have been used principally in righting the animal when accidentally overturned. Most of the specimens show no trace of it, but in the three in which parts of it are preserved, it is turned upward.

These animals seem to be particularly well adapted for enrolment, since the posterior part of the prosoma fits the anterior margin of the thoracetron, and the sides of the adjacent portions of the two shields are so moulded as to fit against one another. Specimen M.C.Z. 4697 may be such an enrolled individual.

Measurements. The holotype (fig. 9) is 10.50 mm. long without the telson. The prosoma is 9.25 mm. long and 15 mm. in greatest width. The thoracetron about 7 mm. long and 12 mm. in greatest width. The thoracetron is partially overlapped by the prosoma. A complete specimen (Yale Univ. Mus. no. 16,913), is 24 mm. long; the prosoma 8 mm., the thoracetron about 6 mm., and the telson 10 mm. long. A paratype (M.C.Z. 4696) is 17 mm. long without the telson, the prosoma 10 mm. long and 13.5 mm. wide, the thoracetron 7 mm. long and 12 mm. wide. An isolated thoracetron (M.C.Z. 4697) is 11 mm. long and 15 mm. wide: an immature specimen (Yale Univ. Mus.) is 13 mm. long, the prosoma 4 mm., the thoracetron 3 mm. and the telson 6 mm. long.

Formation and locality. It is curious that this little form has not been described previously, for it seems to be fairly common in the Francis Creek shale at Mazon Creek, Illinois. The holotype is M.C.Z. 4698, the paratype shown in fig. 7 is M.C.Z. 4696; those shown in figs. 8 and 10 are in the Yale University Museum, where there are several excellent specimens.

It is probable that these specimens have been mistaken for young or incomplete individuals of *Euproöps danae*, but the collection studied contains many young of that species which are so like the adult that there is no justification for such identification.

Genus Pringlia genus nov.

Liomesaspidae with the cardiac lobe well developed. Genotype, *Prestwichia birtwelli* H. Woodward.

Pringlia birtwelli (H. Woodward)

Prestwichia Birtwelli H. Woodward, Geol. Magazine, vol. 9, 1872, p. 440, pl. 10, figs. 9,10; Paleontographical Soc. London, 1878, p. 247, pl. 31, figs. 7a, b, c.
Euproöps Birtwelli H. Woodward, Geol. Magazine, Ser. 6, vol. 5, 1918, p. 468.

Woodward described this species originally as without spines on the border of the thoracetron, but in his last paper listed above he stated that in all probability spines were present, but hidden in the matrix. In view of what is known of the numerous specimens of Liomesaspis that seems highly unlikely.

The general configuration of *Pringlia birtwelli* is almost identical with that of Liomesaspis, but although there are no true dorsal furrows on the prosoma, the cardiac lobe is outlined for its entire length. Moreover, there are distinct genal angles, with a trace of a minute spine. It is not at all likely that the two small spots midway in the head, which Woodward identified as eyes are really such, for they are outside the opthalmic ridges. It is more probable that the eyes are far forward, where the opthalmic ridges turn inward.

The thoracetron shows five rings on the cardiac lobe, each with a small median pustule, and behind them is a longer spine-bearing terminal portion, as in Liomesaspis. The lateral lobes show traces of segmentation.

Measurements. Woodward gives the following measurements: (one line equals about 2 mm.). Entire body; length, 8 lines, greatest breadth, 8 lines. The prosoma is 4 lines long, the thoracetron 4 lines, the telson 4 lines. One would judge from the figure that the telson is incomplete. The proportions are, therefore, about the same as in *Liomesaspis laevis.*

Formation and locality. Only two specimens have ever been found, so far as I can learn. They came from the Coal Measures at the Cornfield Pit, on the south bank of the River Calder, Padiham, Lancashire, England. The generic name is for Dr. John Pringle, in recognition of his years of study of the Coal Measures of Great Britain.

PRINGLIA BISPINOSA spec. nov.

Fig. 11

Only a single prosoma is known. It is roughly subcircular, depressed, without genal spines, but with strong spines at the posterior ends of the opthalmic ridges. The course of each of these ridges is forward

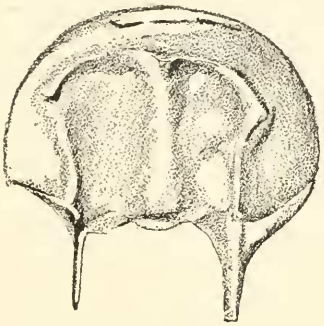

Fig. 11. *Pringlea bispinosa* Raymond. The holotype. Yale Univ. Mus., no. 16911. x 3.

and outward to the eye, which is at about midlength, then forward and inward to the median line, where the two ridges unite at the anterior end of the cardiac lobe. The latter is raised but slightly above the general surface, and tapers uniformly forward.

The greatest width of the prosoma is at the genal angles which are pointed, but without spines.

This species differs from *P. birtwelli* chiefly in that the eyes are further back on the shield.

Measurements. Length of prosoma, 10.5 mm., width at genal angles, 15.5 mm. Length of cardiac lobe, 7 mm., width between eyes, 10 mm.

Formation and locality. The holotype, from the Francis Creek shale at Mazon Creek, Illinois, is no. 16911 in the Yale University Museum.

Genus PROLIMULUS Fritsch

Prolimulus Fritsch, Geol. Magazine, dec. 4, vol. 6, 1899, p. 58, fig., Fauna der Gaskohle und der Kalksteine der Permformation Böhems., vol. 4, 1899–1901, p. 64, figs. 369, 370, pl. 155.

All specimens of the genotype, *Prolimulus woodardi* Fritsch are so badly preserved that this genus can hardly be said to have any

generic characteristics. The one outstanding feature that is significant is that the prosoma has no genal spines, which may indicate relationshp to Liomesaspis, with which genus it agrees further in lacking spines on the thoracetron. It may therefore be placed provisionally in the Liomesaspidae.

According to Fritsch, the prosoma is about 1.5 times as wide as long, the thoracetron somewhat wider in proportion. A specimen in the Museum of Comparative Zoölogy (M.C.Z. 4694) has the following dimensions: length of prosoma, 9.5 mm., width, about 14 mm.; length thoracetron, 7 mm., width 11 mm.

Formation and locality. This species is common in the Permian Gaskohle at Nyran in Bohemia.

Superfamily LIMULACEA nov.

Limulada with the posterior portions of the opthalmic ridges parallel; thoracetron trapezoidal, with movable lateral spines.

Family PALEOLIMULIDAE fam. nov.

Limulacea with opthalmic ridges meeting in front of the eyes, with a narrow doublure on the prosoma, and axial rings on the thoracetron.

Genus Paleolimulus Dunbar

Paleolimulidae with conspicuously lobed intra-opthalmic areas and with lateral lobes of the thoracetron smooth except for rows of nodes near the margin. Genotype, *Paleolimulus avitus* Dunbar.

Dunbar considered the lobation of the "glabella" (intra-opthalmic areas) as the most important characteristic of this genus. This is only partially true, for some almost fully grown specimens of *Euproöps thompsoni* show it, as do many individuals of the Upper Jurassic *Limulus walchi*. In fact, it is not difficult to find specimens of the modern *Limulus polyphemus* which show lobation.

It may be, since only one genus is known, that I have included in the family characteristics some features which are confined to the genus. As mentioned above, in connection with the Belinuracea, it is probable that *Prestwichia randalli* is a member of a more primitive genus than Paleolimulus, to which it has been tentatively referred by Dunbar.

Paleolimulus avitus Dunbar

Pl. 1, pl. 2, figs. 1, 2, 3.

Paleolimulus avitus Dunbar. Am. Jour. Sci., vol. 5, 1923, p. 444, pl. 2, fig. 1, text figs. 2–6.

Dr. Frank M. Carpenter has collected several specimens of this species from the typical locality, Elmo, Kansas, where it is a relatively rare fossil associated with insects and plants in the Lower Permian Wellington shales. They permit me to add a few details to Professor Dunbar's excellent description.

The dorsal surface

To one who has been studying the Euproöpacea, the most striking features of the prosoma are the Limulus-like characteristics of parallel post-ocular opthalmic ridges without spines at the posterior end, the downward flexure of the test at the posterior margin, and the concave areas between the posterior ends of the opthalmic ridges and the tips of the genal spines.

The lateral extension of the first half-segment of the thoracetron is also prognostic of Limulus, and entirely unlike anything seen in the Euproöpidae. It shows, however, a much more primitive condition than in modern Limulus in that the distal spines are turned downward instead of upward, and extend out beyond the greatest width of the remainder of the shield. They are, in fact, somewhat longer than shown in Dunbar's restoration, whereas in *Limulus polyphemus* they are short. In the Jurassic *L. walchi* they appear to be in a somewhat intermediate condition, less strongly developed.

No specimen in our collection shows the movable spines, or stylets, but that they were present is shown by mounds for their attachment. Such can be seen along the margin in figure 2, pl. 2. It is probable that the stylets were in general larger than the two figured by Dunbar.

A peculiar feature, and one which can not be satisfactorily interpreted from the material at hand, is the apparent presence of a free segment behind the thoracetron and above the anterior end of the telson. This is shown on four specimens (M.C.Z. 4659, 4660, 4664, 4668), but all of them leave something to be desired as to detail. The natural interpretation of this segment would be that it corresponds with the transverse process on the anterior end of the telson of modern Limulus. To this process are attached the dorsal muscles which lift the telson. In modern Limulus this process is partly or

entirely concealed when the telson is horizontal in position, and is pulled forward entirely beneath the thoracetron when the telson is lifted. In Paleolimulus, however, the transverse bar does not move under the thoracetron, but is entirely behind it, and, moreover, it has a lateral lappet on each side, so that it has the appearance of a full segment. It may be that it is connected with the telson as in Limulus, in which case it merely represents a primitive condition of the transverse process. Even so, it does suggest that that process was originally a segment of the trunk that has become attached to the telson. The subject is of considerable interest as bearing upon what has become of the posterior (six?) segments of the trunk in the Xiphosura. For illustrations, see pl. 2, figs. 1, 2. It is perhaps best shown by an unfigured specimen (M.C.Z. 4668), where it is definitely free from the thoracetron, and probably free from the telson.

The doublure of the prosoma is narrow. It widens somewhat in the middle of the front, but the posterior edge makes a smooth curve, there being no such angulation as in modern Limulus.

Appendages

All ten of the entire specimens in the Museum of Comparative Zoölogy retain more or less well preserved appendages, in most cases pressed flat against the inner surface of the test. Yet so well did Professor Dunbar describe them from his one specimen that comparatively little can be added.

As in modern Limulus, the coxae were elongate, fixed to the ventral membrane, with the dorsal side open for the intrusion of muscles, the aperture being outlined by a thickened frame. As in Limulus, the five pairs spread outward and forward from the position of the mouth, which presumably was at about the mid-length of the cardiac lobe. The coxae seem proportionally as long as in the modern forms, and they occupy as much space under the cardiopthalmic areas. Their inner ends are but poorly preserved and show no traces of gnathal spines.

Only four specimens (M.C.Z. 4658, 4664, 4665, and 4667) show traces of the chelicerae. They are best preserved in specimen no. 4664, wher they can be seen to be attached beside the posterior end of the camerosome. Two segments project forward and outward, but the pincers are not shown. Specimen no. 4665 shows a pair of pincers ahead of the other four pincer-bearing appendages. They are turned outward, but much nearer the median line than are those behind.

It appears then, that the chelicerae were short, not recurved, and had two segments in addition to a small pair of pincers.

The walking legs are more or less well preserved on all the specimens, but it is impossible to make out the details of the segments. There appear to be three segments in addition to the pincers, as in modern Limulus. They are, perhaps, best shown on M.C.Z. 4662 (Pl. 2, fig. 2). The pincer segment is long, the one proximal to it shorter, apparently almost square when crushed. The details of the one which articulates with the coxa are vague in outline in all specimens. The pincers themselves are best shown on M.C.Z. 4665, which retains all four on the left side and one on the right. The actual pincer part of the outer segments is progressively larger from the second to the fifth appendage, the increase being from a length of 1 mm. to that of 2 mm. The prosoma of this specimen is 8.5 mm. long. The pincers themselves are slender and gently curved, like those of modern Limulus.

The walking legs, although built on the same plan, seem to be more slender, and much less specialized for digging than those of the modern species. They show much less modifications for a downward-turned position.

The sixth pair of legs, the "pushers" are more complete than those on Dunbar's specimen since they show a long slender segment beyond the one with the whorl of flattened setae. Whether or not this segment bears pincers I am not sure, for they are not present on the most complete leg (M.C.Z. 6665). The whorl of blades on the pusher is best shown on M.C.Z. 4662 (Pl. 2, fig. 2).

Several specimens show traces of gills in the thoracetron, the best of them being M.C.Z. 4660 (Pl. 2, fig. 1). They express themselves as concentric curved lines beneath the test on the lateral lobes. Apparently the gross structure is the same as in the modern relatives. The area occupied by the gills extends much farther back, however, almost to the posterior end.

The camerosome is shown by only one specimen, M.C.Z. 4664, and by that only in dorsal outline. It is elongate, narrow, somewhat constricted at the posterior end. Although not fully cleaned out, it appears to be canoe shaped, but not so deeply keeled as in Limulus.

So far as the specimens can be interpreted, the appendages of Paleolimulus differ from those of modern forms only in being somewhat less specialized for digging and in lacking spinose outgrowths. They are by no means suggestive of any primitive condition.

The appendages of Euproöps are less well known, the only really good specimen retaining them being the one described by Packard.[1]

[1] Nat. Acad. Sci., Mem. vol. 3, 1886, p. 146, pl. 5, fig. 3a; pl. 6, figs. 1, 1a.

This specimen lacks the coxae, but they are preserved, in part at least upon a prosoma of *Euproöps thompsoni* (M. C. Z. 4682), a young specimen of *E. laevicula* in the Yale University Museum (no. 16916), and a young individual of *E. danae* (Yale, no. 16910).

The young specimen of *E. thompsoni* has the appendages so imperfectly preserved that no definite conclusions can be drawn. It appears, however, that the coxae were as elongate as in Paleolimulus. The young *E. laevicula* is more important. The coxae have the same direction as in Paleolimulus, but each has a long slender process extending inward under the cardiac lobe. The young *E. danae* have the same radial arrangement of slender coxae under the intra-opthalmic areas as is present in Paleolimulus and Limulus.

So far as one can judge from the photograph, the outer appendages of Euproöps are about as restored by Packard. All are exceedingly slender, even more so than in Paleolimulus, and hence even less adapted for digging. The last pair are probably incomplete, as they show no segment beyond the whorl of three short blades. Such a segment is, however, mentioned in the text. The pincers of the walking legs appear to be slender.